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CONTRIBUTION OF SENSOR FUSION TO URBAN MAPPING: APPLICATION TO SIMULATED SPOT 5-6 DATA

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ABSTRACT: This communication intends to enhance the contribution of a sensor fusion method to urban mapping using the simulated SPOT 5-6 data. A new scheme is proposed for cartography of urban areas which takes into account the multispectral and the multiresolution nature of the data. This process makes use of classification and segmentation. An application of the sensor fusion method to analyse the simulated SPOT 5-6 data is presented. The benefits of using sensor fusion before the application of classification and segmentation are discussed.

1. INTRODUCTION

Urban mapping by the means of satellite images is a promising market for Earth observation in the next decade. For such an application, on the one hand, a high spatial resolution is necessary for an accurate description of the forms and structures within the cities. On the other hand, the different types of land use are better mapped if high spectral resolution images are available. One of the few solutions to this problem is the SPOT 5-6 series of satellites from CNES - the French spatial agency. These satellites will produce images with the same spectral bands than the existing HRV sensors of SPOT 1, 2 and 3 but with an improved resolution in space. The panchromatic band of the future SPOT 5-6 satellites will provide an image with a spatial resolution of 5 m and the multispectral bands, B1, B2 and B3, images with a spatial resolution of 10 m.

Urban mapping from satellite images is usually realized by a manual photo-interpretation. The parameters used are the geometry of the structures in the image and the local contrast allowing to distinguish two different areas in the image. The multispectral nature of the data is not often considered. In section 2, a scheme using automatic processes to prepare the data for the photo-interpretation is proposed. This scheme makes use of classification and segmentation techniques and takes into account the multispectral and the multiresolution nature of the simulated SPOT 5 data. To improve the accuracy of the results provided by these methods, it is proposed to use sensor fusion. The ARSIS method (after its French name "amélioration de la résolution spatiale par injection de structures") allows the improvement, in a set of images with different spatial and spectral resolutions, of the images with the lower spatial resolution up to the best spatial resolution available in this set. This method (Ranchin *et al.* 1996) allowing the preservation of the spectral content of the original images that have to be enhanced, is shortly presented in section 3. An application of ARSIS to the simulated SPOT 5-6 data and the improvement brought by such a method to urban mapping are discussed in section 4.

2. A NEW SCHEME FOR URBAN MAPPING

When a single image or a mosaic of images in the same spectral band is available, the usual method to map urban areas is to photo-interpret it manually. The accuracy of the map is due to the skills of the photo-interpreter. The geometric information and the local contrast are the parameters taken into account for interpreting the images. When multispectral images are available, a classification process can be applied and the spectral and the geometric information are used together.

In the case of the SPOT 5-6 imagery, the multispectral images have a spatial resolution of 10 m and the panchromatic band a spatial resolution of 5 m. A manual photo-interpretation will privilege the information brought by the panchromatic image. Ranchin and Wald (1995) have proposed, in the case of the existing SPOT imagery, to extract roads from the satellite images using a hierarchical ascending classification (Albuisson 1993) and have used sensor fusion for improvement of the accuracy of the mapping. In this communication, it is proposed a new scheme in order to prepare the work of the photo-interpreter and the evaluation of the benefits of using sensor fusion before using this new scheme.

As previously proposed, a hierarchical ascending classification will be performed on the multispectral SPOT 5-6 images at the spatial resolution of 10 m, allowing the discrimination of the roads and buildings. From this classification, a mask containing the areas with roads and buildings will be derived. This mask will be used to reduce the size of the data to process. In order to give the best possible description of the area, a segmentation will be applied to the masked image. The aim of a segmentation is to divide an image in homogeneous areas. Applying such a process on the result of a mask image allows to reduce the processing time and the possible mistakes due to the segmentation algorithm. The used algorithm takes into account the multispectral and the multiresolution nature of the data (Lopez, 1993). It tries to minimize the energy of a function of all the images available, and of their approximations. Bijaoui *et al.* (1995) have compared this algorithm to others for the discrimination of the coastline in synthetic aperture radar imagery. The approximations of the different images available are computed through a scale analysis algorithm (Dutilleux 1987) which allows the representation of an image with coarser and coarser spatial resolutions. An approximation of an image at a given spatial resolution, contains all the structures with a spatial resolution coarser than the given one. The computation of successive approximations of an image allows to discriminate the size of the different structures in an image. A multiresolution representation of an image is obtained and included into the segmentation process. The results of the segmentation computed from the masked image using the multispectral and the multiresolution nature of the data, will be close to a map and can be used to build the final map.

It is obvious that if the multispectral images have a better spatial resolution, the results of their processing will be more accurate. The next section describes shortly a sensor fusion method allowing the improvement of the spatial resolution of an image with respect of its spectral content. The preservation of the spectral content is important due to the use of the multispectral nature of the data in the different steps of the process. If major drawbacks are brought by the sensor fusion method, the performances of the algorithms will be degraded.

3. THE ARSIS METHOD

The ARSIS method was first applied to the case of the existing SPOT imagery (Ranchin *et al.* 1993). This method allows the improvement, in a set of images with different spatial and spectral resolutions, of the spatial resolution of images up to the best spatial resolution available. In the case of the SPOT imagery, the set of images is composed of a panchromatic image with a spatial resolution of 10 m and three XS multispectral images with a spatial resolution of 20 m. ARSIS allows to synthesize XS multispectral images with a spatial resolution of 10 m. Other sensor fusion methods were designed to improve the spatial resolution of images, but an analysis of the different families of methods (Mangolini *et al.* 1995) has shown that in terms of preservation of the spectral content of the original images, ARSIS gives the best achievable results.

This method makes use of the wavelet transform and the multiresolution analysis. The multiresolution analysis allows to compute successive approximations of an image with coarser and coarser spatial resolutions. Associated with the multiresolution analysis, the wavelet transform allows to describe the difference of information existing between two successive approximations. The multiresolution analysis can be reversed and the original image exactly reconstructed from an approximation and the differences of information represented by the wavelet coefficients. The description of the information content of the image with the best spatial resolution (in the case of SPOT, the panchromatic one), is used to model the missing information needed to synthesize the lower spatial resolution image(s) (in the case of SPOT, the XS images) with the best spatial resolution. The model allowing the transformation of the information from the panchromatic to the multispectral images takes into account the physics of both images. The ARSIS method was also applied to the merging of the Thematic Mapper (TM) band 6 (spatial resolution 120 m) of the Landsat satellite with the other bands of TM sensor (spatial resolution 30 m), the merging of TM images with the panchromatic image provided by SPOT and the merging of SPOT XS images (spatial resolution 20 m) with the image provided by the Russian sensor KVR-1000 (spatial resolution of 2 m).

4. EXAMPLE AND DISCUSSION

The simulation of the SPOT 5-6 data is obtained from an airborne Push-Broom sensor similar to the SPOT one. The spatial resolution of images is 1.6 m when the plane flies at 3000 m. The data were processed in order to simulate the radiometric (modulation transfer function, noise, ...) and the geometric qualities of the future SPOT 5-6 images. The panchromatic band is designed with a spatial resolution of 5 m and the multispectral images called B1, B2 and B3, with a spatial resolution of 10m. An extract of the simulated B1 image is presented Figure 1a.

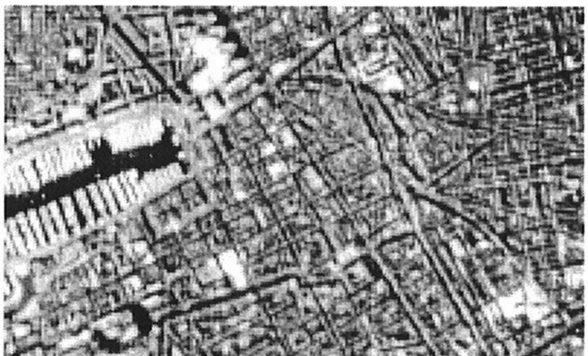

Fig. 1a. Simulated B1 image at 10m

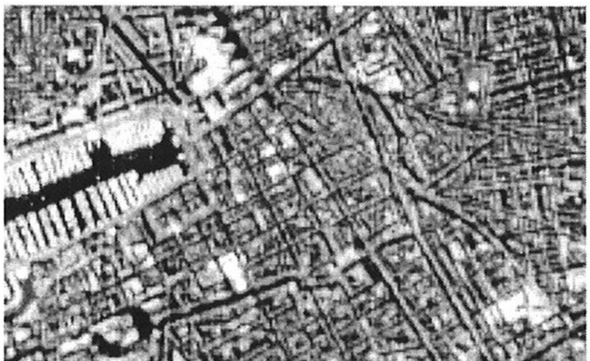

Fig. 1b. Synthesized B1 image at 5 m

This image was acquired over the town of Marseille (France), during the campaign of September 1993. The extract presents a part of the old harbor of Marseille. The hill in the left center of the image is Notre Dame de La Garde. Around this hill, the old town of Marseille shows streets and buildings very difficult to discriminate. The rest of the image is composed of streets and buildings easier to distinguish.
The application of the ARSIS method allows to improve the spatial resolution of the Bi images up to the spatial resolution of the panchromatic image (*i.e.* 5 m), with a respect of their original spectral content. Figure 1b presents the synthesized B1 image at the spatial resolution of 5 m. The improvement between Figure 1a and Figure 1b, brought by the sensor fusion, is on the accuracy of the description of the transitions between the roads and the buildings. The B2 and B3 images are synthesized by the same method at the spatial resolution of 5 m. To assess the possibility of applying the scheme proposed section 2 to this set of images, it is necessary to evaluate the quality of the synthesized images. This evaluation is done following the method proposed by Mangolini *et al.* (1995). The Bi images at the spatial resolution of 5 m do not exist. So it is not possible to compare the synthesized images at 5 m with a reference. To allow an evaluation of the quality of the sensor fusion method, the process is shifted from one scale. The set of images is then composed of the panchromatic image at 10 m and the Bi images at 20 m. These images were provided by CNES in order to evaluate the improvement brought by the SPOT 5-6 data compared to the existing SPOT data. This set allows to synthesize the Bi images at 10 m (called B*) using the ARSIS method and can be compared on a pixel basis through the original Bi images at 10 m. A pixel to pixel difference is computed and some statistical parameters are presented in Table 1.

	B1	B2	B3
Bias (ideal: 0) relatively to the mean of B	0.124 0.232 %	0.119 0.174 %	0.136 0.148 %
Actual variance - variance B*(ideal: 0) relatively to the actual variance	30.9 16.3 %	61.6 16.9 %	85.7 12.6 %
Actual entropy - entropy B*(ideal: 0) relatively to the actual entropy	0.077 1.97 %	0.092 2.12 %	0.075 1.60 %
Correlation coefficient between B and B* (ideal: 1)	0.95	0.95	0.95
Standard deviation of the differences (ideal: 0) relatively to the mean of B	4.38 8.17 %	6.10 8.95 %	8.32 9.04 %

Table 1. statistics on the differences between B and B* for the image of Marseille (France).

The bias denotes a systematic error which is null here. For all images the results are rather good. The differences of the variances and of the entropies are representative of overall changes on the information content. The correlation coefficient is an indicator of the global similitude of the B* and B images. The standard deviation of the differences images assesses the precision of the estimation on a pixel basis. The results find for this image are worse than those found in the case of the existing SPOT imagery but the representation of the information by the B* images compared to the B images is still good. This difference can be explained by the richness of the information contained in this image. The correlation coefficients of the images are 95 %. A part of the information content is lost compared to the B images but the representation provided by the B* images is close to "what the sensor measures at 10 m". It is assumed that the evolution of these results between 10 and 5 m is rather small. Hence, the B images synthesized at 5 m will be close to "what the sensor will measure at 5 m".
The spectral content of original images is preserved and so it is possible to use the synthesized images at 5 m in the classification and the segmentation processes.

5. CONCLUSION

A new scheme for lighten the work of the photo-interpreter for the mapping of urban areas, was described. To improve the accuracy of the processing it was proposed to use sensor fusion. An evaluation of the quality of the synthesized images from the SPOT 5-6 data at the best spatial resolution available in the set of images has shown the preservation of the spectral content of the images. In the future, the proposed scheme will be applied with and without the synthesized images and a evaluation of the mapping will be achieved in order to demonstrate the benefits of using sensor fusion in this application.

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